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Required Data/Guidelines for Payload/Shuttle Electromagnetic Compatibility Analysis

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Space Shuttle Integration and Operations Office
Cargo Engineering Office
Payload Integration Engineering Office
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Houston, Texas

DESCRIPTION OF CHANGES TO

REQUIRED DATA/GUIDELINES FOR PAYLOAD/SHUTTLE
ELECTROMAGNETIC COMPATIBILITY ANALYSIS

CHANGE NO.	DESCRIPTION/AUTHORITY	DATE	PAGES AFFECTED
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NSTS 21288

REQUIRED DATA/GUIDELINES

FOR

PAYLOAD/SHUTTLE

ELECTROMAGNETIC COMPATIBILITY ANALYSIS

Prepared by

Art Reubens Date December 28, 1993
Art Reubens

of

Payload Integration Engineering

Lai-iun Lo Date 12/28/93
Dr. Lai-iun Lo

and

Eric Chan Date 12/28/93
Eric Chan

of

Rockwell Space Operations Company
Systems Integration

Approved by

George W. Sandars Date 1-3-94
George W. Sandars, Manager
TJ2/Payload Integration Engineering Office

Larry E. Bell Date 12-28-93
Larry E. Bell, Manager
TJ/Cargo Engineering Office

FOREWORD

This document defines the format and content of the payload electromagnetic data required for the Space Shuttle to integrate a payload into the flight and ground operations. The schedule for submittal of data by a specific payload are identified in the Payload Integration Plan (PIP).

The customer is requested to provide the data defined, on schedule, sign the title sheet, and return the completed data to the Electromagnetic Compatibility (EMC) group of the Payload Integration Engineering Office/TJ2.

The EMC group will review the data for Space Shuttle implementation and contact the customer if further review of the data is required for amplification, correction, or clarification.

Date 1-19-94

Cheever H. Lambert, Manager
TA/Space Shuttle Integration and Operations Office

PREFACE

This document describes the data requirements for preparation of a Payload's Electromagnetic Data Book, consisting of Radio Frequency (RF) Data, Electromagnetic Compatibility (EMC) Test Data, and Thermal Blanket Data. The requirements specified in this document are written for a general payload; however, requirements applicable or not applicable to a specific payload will only be added or deleted by mutual agreement.

All data submissions made in response to this document are to be reproducible masters and include a signed signature page and a preface page having the same content and format as shown on pages 14, 15, and 16.

The schedule for each payload to submit these required data is defined in paragraph 6.3 and the schedule in section 15.0 of the individual Payload Integration Plan (PIP). The schedule for all payloads is given in the PIPs as follows:

PAYLOAD Type	RF Data (Transmitters, Receivers, and Antennas)	EMC Test Report	Thermal Blanket Design to Preclude ESD
Spacelabs (MSFC Managed) SLM	N/A	5 months prior to launch	N/A
Spacelabs (Non-MSFC Managed) SLB	N/A	5 months prior to launch	N/A
Spacehabs	90 days prior to CIR	5 months prior to launch	N/A
Attached Payloads ATT	90 days prior to CIR	60 days prior to CIR	60 days prior to CIR
Deployable-type Payloads DEP	90 days prior to CIR	60 days prior to CIR	60 days prior to CIR
Deployable/Retrievable Type Payloads DRP	90 days prior to CIR	60 days prior to CIR	60 days prior to CIR

Small Payload Accommodation SML	N/A	60 days prior to CIR	60 days prior to CIR
Hitchhiker (exception)	N/A	4 months prior to launch	60 days prior to CIR
Middeck-type Payloads MDK			
Standard	N/A	4 months prior to launch	N/A
Nonstandard	N/A	4 months prior to launch	N/A
Complex	90 days prior to CIR (if applicable)	60 days prior to CIR	N/A
Get-Away Special Payloads GAS	90 days prior to CIR (if applicable)	N/A but: 4 months prior to launch with door cover	N/A
Space Station Freedom Program SSF	N/A	60 days prior to CIR	60 days prior to CIR

The Payload Electromagnetic Data, consisting of RF data, EMC Test Data, and Thermal Blanket design data, should be sent to the EMC engineer:

Art Reubens/TJ2
Payload Integration Engineering Office
National Aeronautics and Space Administration (NASA)
Lyndon B. Johnson Space Center (JSC)
Houston, Texas 77058

Telephone: 713-483-1223

Equipment and/or design changes, data revisions and updates, questions, problems-in-work, and comments should be transmitted to Mr. Reubens without delay.

CONTENTS

1.0 INTRODUCTION

The customer-provided data in this document is used by the Electromagnetic Compatibility (EMC) group in the Payload Integration Engineering Office to conduct analyses and determine the EMC of the payload to the Space Shuttle and comanifested payloads in the payload bay. If the payload is located in the cabin, the analyses determine the EMC with the crew physiology, cabin equipment, and cabin comanifested payloads.

a. Radio Frequency (RF) Data - The RF data delineated in section 2.0 is used to conduct a worst-case beat frequency analysis to assess the compatibility of all transmitters, receivers, and antennas. If any marginal incompatibilities are disclosed, experimental verification and clarification of the significance of the frequency and amplitude conflict may be conducted at the Lyndon B. Johnson Space Center (JSC) Electronic Systems Test Laboratory (ESTL). The locations of Orbiter antennas that are used on-orbit are delineated in the ICD 2-19001. The general locations of all Orbiter antennas are provided in figure 1-1.

   The payload transmitter/antenna system data is also used to determine the radiated field intensities impinging on the Extravehicular Activity (EVA) crew, other payloads, and the Space Shuttle. Consideration is given to the Line of Sight (LOS) geometries from antennas to payloads that are berthed, being deployed and retrieved during free flight.

   RF incompatibilities may result in the generation of proposed mission RF constraints. These constraints are first coordinated with the mission's Flight Director and the Mission Operations Directorate (MOD) Communications section. Then the constraints are inserted into the mission's Flight Requirements Document (FRD), NSTS 17462-(mission #). The constraints may include, but are not limited to

   1. Antenna selection restrictions

   2. Required frequency channel selection

   3. Restricted power level selection

   4. Transmitter turn-off to preclude interference or overexposure of equipment or crew during certain operational phases

b. Payload EMC Test Data - Unintentional Emissions - The payload customer is required to provide a test report providing the payload's and associated Airborne Support Equipment's (ASEs) unintentional conducted and radiated emissions as delineated in section 3.0. This report is used to certify that the following do not exceed the limits set forth in NSTS 07700, Volume XIV, Attachment 1, ICD 2-19001, Shuttle Cargo Standard Interfaces:

   1. Payload's and ASE's unintentional conducted noise injected into the Orbiter's power and return lines, and the

   2. Payload's and ASE's unintentional radiated noise exposing the Orbiter and co-manifested payloads

c. Payload EMC Test Data - Susceptibility Thresholds (Levels of Immunity) (or Maximum Test Levels as Run) - Reference MIL-STD-1818 (USAF) Electromagnetic Effects Requirements for Systems, paragraph 4.1 states: "Wide use of high power RF transmitters, sensitive receivers, other sensors, and additional electronics creates a potential for problems within the system or from external influences. The system must be designed to be compatible with itself, other systems, and the external electromagnetic environment to insure required performance and to prevent costly redesigns after the fact for resolution of problems."

   In order to establish susceptibility margins for all safety-critical functions, it is required that the electrical and electronic systems sustain the electromagnetic environment defined in the payload's unique Interface Control Document (ICD), and demonstrate appropriate safety margins as given in MIL E-6051D; i.e., +6 dB margin for Conducted Susceptibility over Conducted Emissions environment, +6 dB margin for Radiated Susceptibility over Radiated Emissions environment, and +20 dB margin for Electroexplosive Devices (EEDs).

   Mission safety and mission success may be more readily assured if the conducted and radiated electromagnetic environment is compared to the actual susceptibility thresholds (immunity levels) as determined by test, to determine safety margins.

d. Electrostatic Discharge (ESD) - The Thermal Blanket Design and Test Data delineated in section 4.0 shall demonstrate that the thermal blankets do not constitute an ESD threat in the closed payload bay. ESD could ignite an explosive gas mixture in the payload bay during ascent and descent, should it exist.

Significant electrostatic charging mechanisms, if any exists, during any mission phase, must be identified and shown to be nonhazardous.

2.0 RF DATA REQUIRED FOR THE JSC EMC FREQUENCY ANALYSIS

2.1 Transmitter System Data

The payload is to supply the following transmitter data:

a. Transmitter system name

b. Type: Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), Continuous Wave (CW), Pulse

c. Center frequency in MHz

d. Plus and minus frequency swing in MHz

e. Typical modulation frequency in MHz, if applicable

f. Pulse width in microseconds (μsec), if applicable

g. Pulse Repetition Frequency (PRF) in Pulses Per Second (PPS), if applicable

h. Output in watts at transmitter terminals, not including cable or waveguide loss to antenna(s)

i. Number of associated antennas and power distribution and selection scheme, if any

j. Cable or waveguide loss in decibels (dB) between the transmitter and associated antenna(s)

k. Identify turn on, turn off, and power level selection scenario in relation to checkout, deployment, stationkeeping, maneuvers, and retrieval, as applicable

2.2 Receiver System Data

The payload is to supply the following receiver data:

Note: If the receiver is not activated in the payload bay, provide as a minimum: 2.2a, b, k, l, m, n, o, p, q, s, x; for damage threat assessment.

a. Receiver system name

b. System center frequency in MHz

c. System 3 dB bandwidth in MHz at final Intermediate Frequency (IF) stage

d. System 60 dB bandwidth in MHz at final IF stage

e. System maximum sensitivity in dBm

f. Local oscillator frequency in MHz and amplitude in dBm

g. First IF in MHz

h. First IF 3 dB bandwidth in MHz

i. First IF 60 dB bandwidth in MHz

j. Second IF frequency in MHz

k. Second IF frequency 3 db bandwidth in MHz

l. Diplexer, Triplexer, or Quadriplexer insertion loss as applicable

m. Preselector filter type

n. Preselector filter maximum attenuation in dB

o. Preselector filter 3 dB bandwidth

p. Preselector filter 60 dB bandwidth

q. Preselector filter, number of poles

r. Number of associated antennas and antenna selection scheme

s. Cable or waveguide loss in dB between the receiver and each associated antenna

t. External Low Noise Amplifier (LNA) gain characteristics, if applicable

u. Image rejection filter attenuation in dB

v. Maximum "in band" power (dBm) for proper receiver operation. (Threshold of overdriving the receiver)

w. Identify turn on, turn off scenario in relation to checkout, deployment, stationkeeping, maneuvers, and retrieval, as applicable

x. Power threshold to damage receiver (dBm) at receiver terminals

y. Worst case isolation between receiver and associated transmitter

2.3 Antenna System Data

The payload is to supply the following transmitter data:

a. System name associated with antenna

b. Antenna locations in Orbiter Xo, Yo, Zo coordinates (see figure 2-1).

   1. For dish antennas, give the feed location.

   2. If the antenna Xo is not yet known, provide the antenna's relative Xo axis location to the payload's keel trunnion.

   3. If there is no keel trunnion, use an identified payload longeron trunnion.

   4. Mechanical drawings shall be submitted to identify all the payload antennas describing the specific locations and Fields of View (FOV) in the payload bay.

   5. If applicable, the drawings should also describe the specific relocations of payload antennas that are extended, retracted, rotated, or swung to a new FOV

during payload deployment and retrieval (if applicable) by the Remote Manipulator System (RMS) or other means.

6. Identify the Payload Axis System (PAS) and location of the PAS origin.

7. Locations of receiving antennas shall be provided even if the associated receiver is not activated until the payload is at great range before turn on. (Concern is unactivated receiver front-end burnout when exposed to high field intensities.)

c. List associated antennas (other antennas feeding from or to the same system).

d. Antenna gain on boresight in dB.

e. Antenna Field Polarization (linear, Right Hand Circularly Polarized (RHCP), Left Hand Circularly Polarized (LHCP))

f. Antenna effective diameter in meters.

g. Antenna pointing from the radial in degrees of elevation and azimuth (antenna boresight tilt angles from a defined reference plane (see figure 2-2)).

h. Antenna efficiency.

i. Antenna radiation plot

1. Polar Plot or

2. Radiation Distribution Plot (RDP)

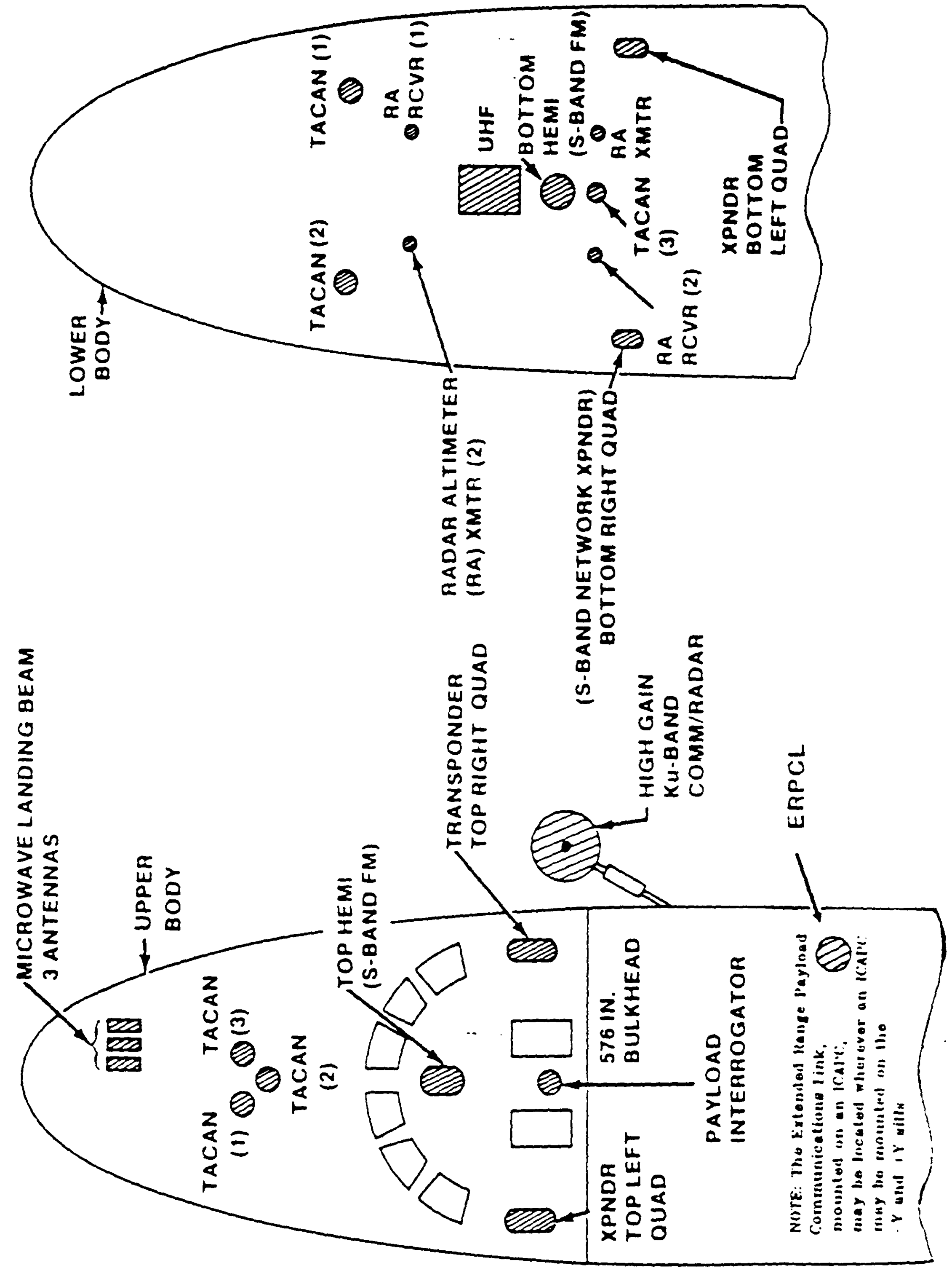
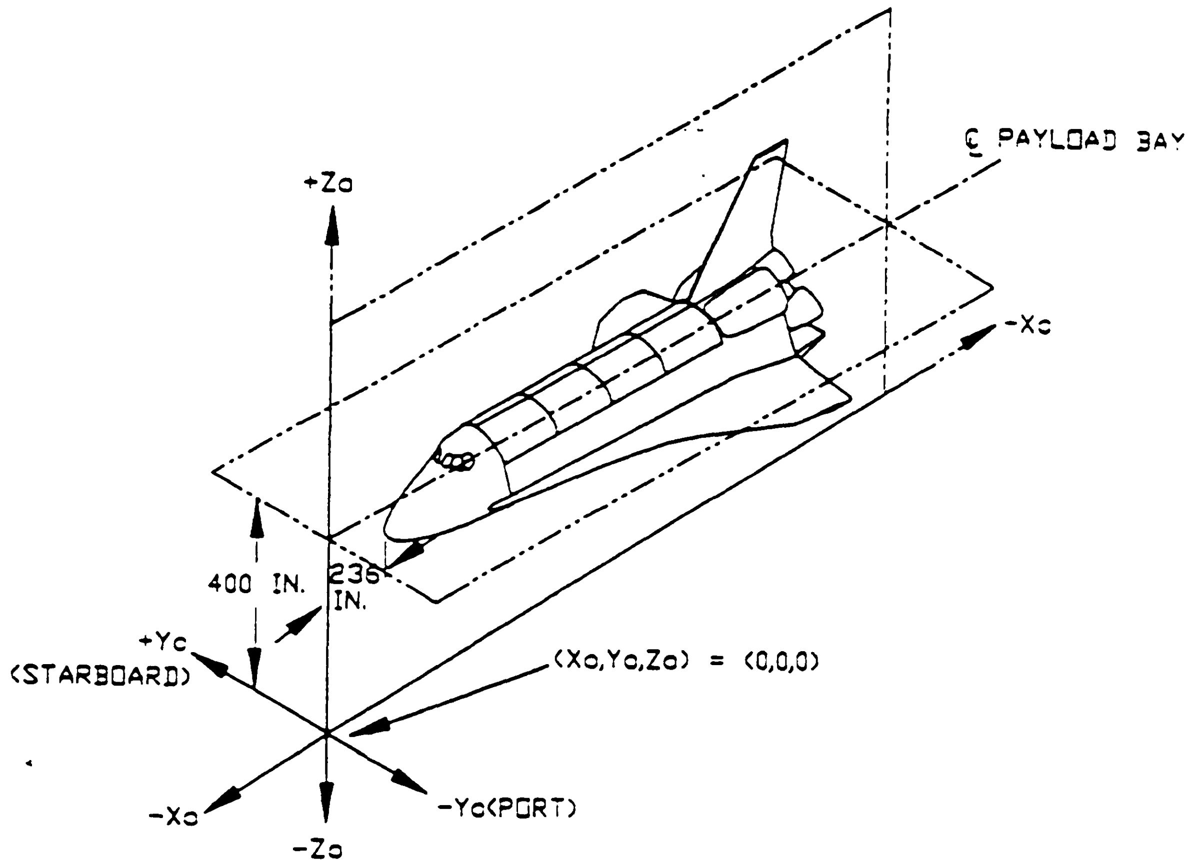


Figure 1-1.- Orbiter antennas.



ORIGIN:	IN THE ORBITER PLANE OF SYMMETRY, 400 INCHES BELOW THE CENTERLINE OF THE PAYLOAD BAY AND AT ORBITER X STATION = 0.
ORIENTATION:	THE Xo AXIS IS THE VEHICLE PLANE OF SYMMETRY, PARALLEL TO AND 400 INCHES BELOW THE PAYLOAD BAY CENTERLINE. POSITIVE SENSE IS FROM THE NOSE OF THE VEHICLE TOWARD THE TAIL.
	THE Zo AXIS IS IN THE VEHICLE PLANE OF SYMMETRY, PERPENDICULAR TO THE Xo AXIS, AND POSITIVE UPWARD IN THE LANDING ATTITUDE.
	THE Yo AXIS COMPLETES A RIGHT-HANDED SYSTEM.
CHARACTERISTICS:	RIGHT-HANDED CARTESIAN COORDINATE SYSTEM. THE STANDARD COORDINATE DESIGNATION IS o (E.G., Xo, Yo, Zo

Figure 2-1.- Orbiter rectangular coordinate system.

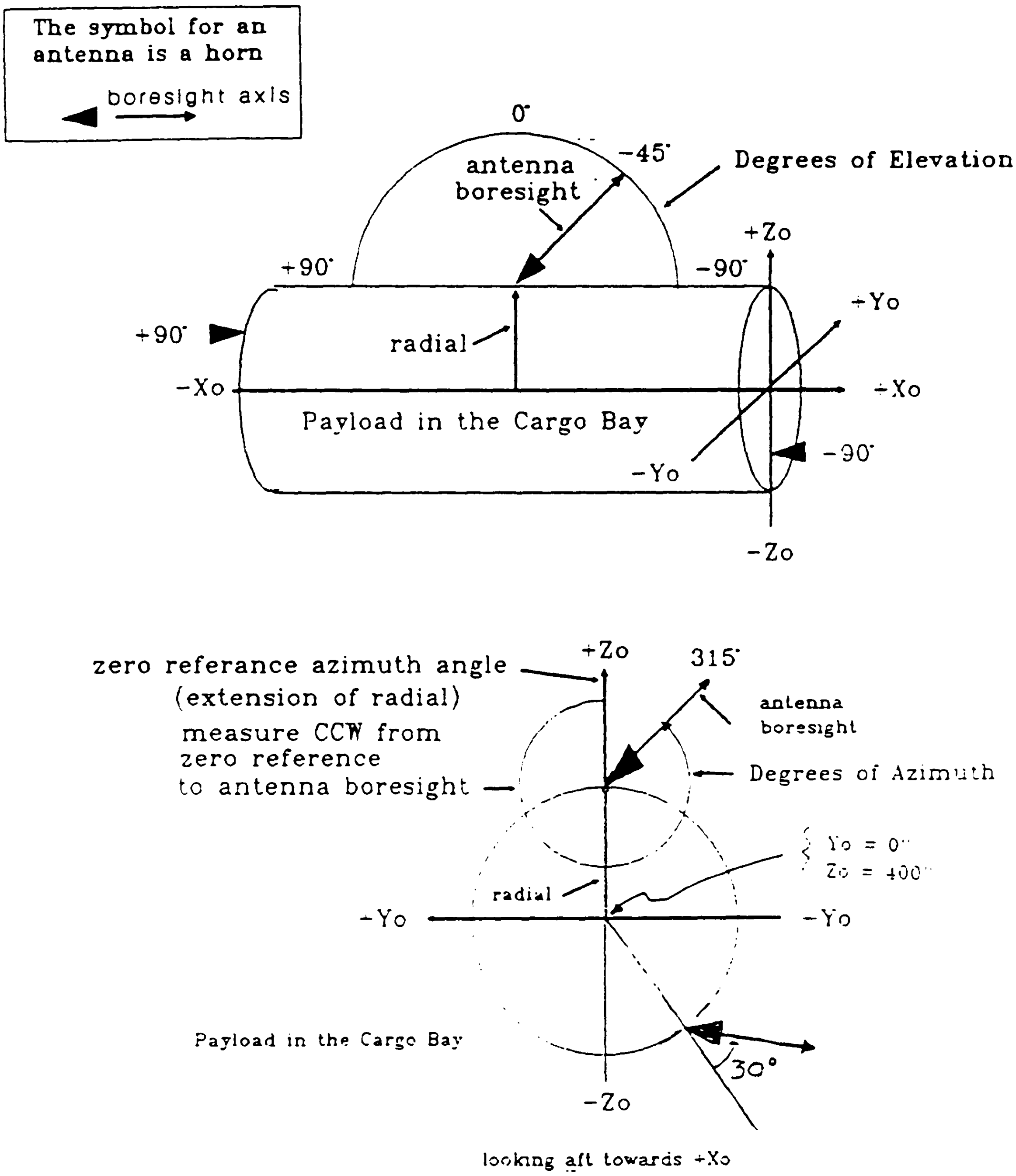


Figure 2-2.- Payload antenna pointing: azimuth and elevation.

3.0 PAYLOAD EMC TEST DATA

a. The EMC Test Plan, that the customer uses to determine the payload's unintentional Radiated and Conducted emissions, should employ the test methods in MIL-STD-462, "Measurement of Electromagnetic Interference Requirements."

The emissions submitted in the EMC Test Report will be reviewed by the EMC group at JSC/TJ2 to determine compliance with the Unintentional Radiated Emissions Limits and the Conducted Emission Limits defined in the payload-unique ICD.

If the payload customer desires to limit the customary range of radiated and/or conducted frequencies tested due to some unique characteristics of the payload, or usage scenario, then a request should be made to JSC/TJ2 at a Technical Interchange Meeting (TIM) or by telephone or FAX, very early in the payload integration process.

b. The Shuttle's electromagnetic environment should be used to help tailor the electromagnetic immunity design levels of the payload.

The susceptibility test data has to indicate that the payload's immunity levels are greater than the Shuttle's environmental emission levels, as defined in the payload-unique ICD. The payload customer's EMC Test Plan should employ the test methods in MIL-STD-462 for Radiated and Conducted Susceptibility testing.

3.1 Unintentional Radiated and Conducted Emissions

a. Unintentional radiated emissions

1. Broadband electric field intensity in dBμV/m/MHz vs. frequency in MHz are less than the limits described in figure 10.7.3.2.2.1-1 in the ICD 2-19001.

2. Narrowband electric field intensity in dBμV/m vs. frequency in MHz are less than the limits described in figure 10.7.3.2.2.1-2 in the ICD 2-19001.

3. AC magnetic flux density in dBpT vs. frequency (30 Hz to 50 KHz) are less than the limits described in paragraph 10.7.3.2.1.1 in the ICD 2-19001.

4. The source(s) of dc (static) magnetic flux densities greater than 170 dBpT shall be identified and tabulated. The location of each identified electromagnet and/or permanent magnet shall also be tabulated, in Orbiter body coordinates.

b. Conducted emissions

1. The dc ripple current in dBμA vs. frequency in Hz are less than the limits described in paragraph 10.7.3.1.1 in the ICD 2-19001.

2. The dc transient data in voltage excursions vs. time in seconds are less than the limits described in paragraph 10.7.3.1.1 in the ICD 2-19001.

3. The ac ripple current in dBμA vs. frequency in Hz are less than the limits described in paragraph 10.7.3.1.2 in the ICD 2-19001.

4. The ac transient data in voltage excursions vs. time in seconds are less than the limits described in paragraph 10.7.3.1.2 in the ICD 2-19001.

If any electronics or electrical design changes are made to the payload after the EMC testing is completed, the EMC group at JSC/TJ2 should be notified immediately to determine if any retest and/or analysis of the payload is necessary.

3.2 Radiated and Conducted Susceptibilities (Noise Immunity)

When a payload is subjected to the electromagnetic environment generated by the Shuttle and does not exhibit any malfunction or degradation of performance, it is said to operate properly; i.e., the payload's electromagnetic immunity levels exceed the electromagnetic environmental levels.

The payload customer is required to provide a Statement of Assurance that the payload will operate properly when exposed to the radiated and conducted emissions environment levels described in the payload's unique ICD.

The voluntary decision to provide the actual susceptibility threshold levels, or the test level maximums, is an option available to the payload customer. These data are desirable and will provide more evidence for analysis to assure mission success.

If the payload customer has identified an EMI induced hazard to the Orbiter or comanifested payloads, then a detailed Payload EMI Susceptibility Test Report shall be required for submittal to the EMC group at JSC/TJ2.

If there are no safety-critical EMC issues for the payload, and the payload customer determines that the payload has electromagnetic immunity exceeding the electromagnetic environment in and about the Shuttle, as required by the mission scenario, then a "Statement of Assurance" in the EMC Test Report shall suffice to indicate that the payload operates properly in the electromagnetic environment.

4.0 THERMAL BLANKET ESD

Multilayer thermal blankets' construction is quite similar, electrically, to electrical capacitors.

	TYPICAL MATERIAL CONSTRUCTION	
	Multilayer Thermal Blankets	Electrical Capacitors
conductors or plates	Vacuum Deposited Aluminum (VDA) on Kapton sheets	aluminum conducting outer layers
insulation medium	alternating, separation layers of insulating dacron polyester	separation layer of a dielectric

Both the multilayer thermal blankets and electrical capacitors have large electrical capacitance values.

During launch and landing, vibration and large temperature excursions provide the triboelectric charging mechanisms for the blankets. These blankets can and have been charged up to thousands of volts. ESD of very low energy levels can ignite flammable gases in the payload bay. The most dangerous mission phase is from deorbit through descent and rollout.

The closed payload bay is always assumed to have flammable gases or explosive gas mixtures. The Orbiter has hydrogen and oxygen storage tanks and distributive plumbing in the payload bay for the fuel cells. Payloads often have highly active fuels and oxidizers and would remain in the payload bay during Return to Landing Site (RTLS) and Abort Once Around (AOA) landings, or due to a failure that necessitated a deployment-abort.

Therefore, a payload's multilayer thermal blankets have to be electrostatically bonded to payload structure, which is, in turn, bonded to the Orbiter's structure. This will drain the electric charges to the point where the blankets' voltages and payload structure are nearly at the same potential.

This section contains the report requirements for payload's Thermal Blanket Design and the Blanket's Ground Tab(s) resistance test data to payload structure.

4.1 Thermal Blanket Design

The payload customer shall provide data or drawings that describe the payload's exterior thermal blanket(s) design.

a. Type or build-up of the insulation layers and the details on the method of bonding of the layers to each other.

b. Dimensions of each blanket section - Sections of blankets physically connected to each other, but electrically isolated from each other shall be considered to be individual blankets for bonding purposes.

c. Location of bonding tabs and test tabs on each blanket section.

4.2 Thermal Blanket Test Data

The measured dc resistance in Ohms from all grounding tabs to payload structure shall be documented.

5.0 PAYLOAD DATA REPORTS SIGNATURE AND PREFACE PAGES

REQUIRED PAYLOAD ELECTROMAGNETIC DATA PER NSTS 21288

FOR

(name of payload)/Shuttle

ELECTROMAGNETIC COMPATIBILITY ANALYSIS

(date)

PREPARED BY: ______________________________ Date ______
(preparer's typed name)

APPROVED BY: ______________________________ Date ______
(payload representative's typed name)
PAYLOAD REPRESENTATIVE

Prepared by
(name of manufacturer or testing contractor or customer)

For

Payload Integration Engineering Office (TJ2)
Cargo Engineering Office

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

Payload Data Reports signature page (example only).

PREFACE

This document contains the Electromagnetic Data of the (payload name) for the JSC/TJ2 analysis to determine:

a. Electromagnetic Compatibility (EMC) (Radiated and Conducted) as required, between this payload and

   1. Space Shuttle

   2. Co-manifested payloads (attached or deployable)

   3. Government-furnished Equipment (GFE)

   4. Crew physiology

   5. Extravehicular Mobility Unit (EMU)

   6. Manned Maneuvering Unit (MMU)

   7. Simplified Aid for EVA Rescue (SAFER)

   8. Launch and Landing Site Transmitter/Antenna Systems

b. Proper design and static bonding to preclude Electrostatic Discharge (ESD)

   1. In the payload bay

   2. In the cabin

   3. During docking with other space-borne objects

   4. During payload retrieval

c. Radio Frequency (RF) compatibility of all activated mission transmitter/antenna systems vs. all mission receiver/antenna systems considering transmitter power choices, relative antenna ranges and lines-of-sight between radio systems, and RF system usage scenarios.

This document is the single authoritative source for (payload name) (abbreviation of name) EMC input data. If there is any conflict between the Radio Equipment usage or configuration scenario in this document and the Payload Integration Plan (PIP), the PIP shall take precedence. Any requirements submitted in this document that are not within the scope of the PIP will not be considered binding on the National Aeronautics and Space Administration (NASA) for implementation.

It is understood that the EMC analysis of this payload may have different results on different missions.

Comments and corrections, notice of equipment design changes affecting these data as well as requests for explanations or information concerning the EMC of (abbreviation of payload name) should be directed to

Art Reubens/TJ2
Electromagnetic Compatibility
Payload Integration Engineering
NASA/Lyndon B. Johnson Space Center (JSC)
Houston, Texas 77058
Telephone: 713-483-1223

Payload Data Reports preface page (example only)

APPENDIX A

KEY DEFINITIONS

ELECTROMAGNETIC COMPATIBILITY (EMC). The capability of electrical and electronic systems, equipment, and devices to operate in their intended electromagnetic environment with a defined margin of safety and at design levels of performance without suffering or causing degradation as a result of electromagnetic interference.

ELECTROMAGNETIC ENVIRONMENT. The totality of electromagnetic phenomena existing at a given location.

CONDUCTED NOISE. Undesired electromagnetic emissions propagated along a power or signal conductor. It may consist of steady-state noise, usually given as current vs. frequency and transient noise, usually given as voltage excursions vs. time.

RADIATED NOISE: Undesired electromagnetic emissions that are radiated from any unit, antenna, cable or interconnecting wiring. It may consist of electric field intensity vs. frequency or magnetic flux density vs. frequency.

ELECTROMAGNETIC INTERFERENCE (EMI). Any electromagnetic disturbance, conducted or radiated, whether intentional or not, which interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic/electrical equipment.

MARGINS. The difference between the subsystem/equipment design level (susceptibility threshold, or level of immunity) and the subsystem/equipment stress (emission) level.

RADIO FREQUENCY (RF) COMPATIBILITY. The ability of the various antenna-connected RF receiver and transmitter subsystems contained within a system to function properly without performance degradation caused by antenna-to-antenna coupling between any two subsystems.

TAILORING. Tailoring is the process by which the requirements of a standard are adapted (that is, modified, deleted, or supplemented) to the characteristics or operational requirements of the item under development. The tailoring process does not constitute a waiver or deviation.

GROUNDING. The bonding of an equipment case, frame, or chassis to an object or vehicle structure to ensure a common potential. The connection of an electric circuit or equipment to Earth or to some conducting body of relatively large extent which serves in place of Earth.

BOND. Any fixed union existing between two objects that results in electrical conductivity between the two objects. Such union occurs either from physical contact between conducting surfaces of the objects or from the addition of a firm electrical connection between them.

ELECTROSTATIC DISCHARGE. A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field.

STATIC ELECTRICITY. The stationary electrical charge produced and accumulated or stored on the surface of materials due to triboelectric charge generation (friction, rubbing, touching and parting, particle impingement, adhesive forces during separation of materials) or electric field inducement.

APPENDIX B

ACRONYMS AND ABBREVIATIONS

A/m	Amperes per meter (magnetic field intensity)
AM	Amplitude Modulation
AOA	Abort Once Around
APC	Auxiliary Payload Carrier
ASE	Airborne Support Equipment
CIR	Cargo Integration Review
CW	Continuous Wave
dB	decibel
dBi	decibels gain above an isotropic antenna
dBic	decibels gain above an isotropic circularly polarized antenna
dBil	decibels gain above an isotropic linearly polarized antenna
dBm	decibels above one milliwatt (power)
dBW	decibels above one Watt
dBpT	decibels above one picoTesla (magnetic flux density)
dBμA	decibels above one microampere (current)
dBμV/m	decibels above one microvolt per meter (electric field intensity)
dBμV/m/MHz	decibels above one microvolt per meter per megahertz
DF	Duty Factor (PPS X PW), decimal part of the time that a RADAR device is radiating. DF = 1.0 = Continuous Wave (CW)
EED	Electroexplosive Device
EMC	Electromagnetic Compatibility
EMCFA	Electromagnetic Compatibility Frequency Analysis
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
ERPCL	Extended Range Payload Communications Link
ESD	Electrostatic Discharge
ESTL	Electronic Systems Test Laboratory
EVA	Extravehicular Activity

FM	Frequency Modulation
FOV	Field of View
FRD	Flight Requirements Document
FSK	Frequency Shift Key (modulation)
g	gauss = 0.0001 Tesla (magnetic flux density)
GFE	Government-Furnished Equipment
GHz	Gigahertz
GSFC	Goddard Space Flight Center
Hz	Hertz
ICAPC	Increased Capacity Auxiliary Payload Carrier
ICD	Interface Control Document
IF	Intermediate Frequency
JSC	Lyndon B. Johnson Space Center
KHz	Kilohertz
KSC	John F. Kennedy Space Center
LeRC	Lewis Research Center
LHCP	Left Hand Circularly Polarized (antenna)
LOS	Line of Sight
LNA	Low Noise Amplifier
MHz	Megahertz
MMU	Manned Maneuvering Unit
MOD	Mission Operations Directorate
MSBLS	Microwave Scanning Beam Landing System
MSFC	George C. Marshall Space Flight Center
mW/cm^2	milliwatts per square centimeter (power density)
NASA	National Aeronautics and Space Administration
NSI	NASA Standard Initiator
PAS	Payload Axis System
PIP	Payload Integration Plan
PM	Phase Modulation
POWG	Payload Operations Working Group
PPM	parts per million
PPS	pulses per second = PRF
PRF	Pulse Repetition Frequency = PPS
PSK	Phase Shift Key (modulation)
pT	picoTesla (magnetic flux density)
PW	Pulse Width in microseconds

RA	Radar Altimeter
RADAR	Radio Detection and Ranging
RDP	Radiation Distribution Plot
RF	Radio Frequency
RFI	Radio Frequency Interference
RHCP	Right Hand Circularly Polarized
RMS	Remote Manipulator System
RTLS	Return to Landing Site
SIP	Standard Integration Plan (PIP "boiler plate")
SAFER	Simplified Aid for EVA Rescue
T	Tesla = one Weber per square meter (magnetic flux density)
TACAN	Tactical Air Navigation
TIM	Technical Interchange Meeting
V/m	Volts per meter (electric field intensity)
VDA	Vacuum Deposited Aluminum
W	Watts
W/m^2	Watts per square meter (power density)
WCCS	Wireless Crew Communication System
Xo	Orbiter X Structural axis (nose -, tail +)
XPNDR	Transponder
Yo	Orbiter Y Structural axis (port [left] -, starboard [right] +)
Zo	Orbiter Z Structural axis (down -, up +)
μsec	microseconds